



## *SET™ Technology: The Facts*



**ENVENTURE**  
*SET. The Standard.*

## *An Introduction to SET™ Technology*

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When reaching bottom on time and reducing drilling costs depends on you, Enventure provides the means to make that happen with Solid Expandable Tubular (SET™) Technology. This technology essentially changes how the main load-carrying member around which all well designs are built, namely, the casing, is installed. Just as the transistor represented a fundamental change in electronics by replacing vacuum tubes, SET Technology offers a cost-effective, reliable approach to the way wellbores are planned and constructed.

Enventure, the leader in solid expandable tubulars, capitalized on the viability and versatility of this technology and developed a product line that:

- » allows you to reach the new bottomhole targets with optimal diameter for a maximum return-on-investment
- » reduces the tapering effect of telescoping casing strings by reclaiming the clearances required between conventional casing strings
- » enables the well-construction process to remain on schedule even if adverse downhole conditions exist
- » allows use of smaller, lower cost rigs

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|--|---------------------------|
| <i>An Introduction to SET Technology</i> . . . . . | <i>Inside Front Cover</i> |
| <i>The Enventure Solution</i> . . . . .            | <i>2</i>                  |
| <i>SET Technology</i> . . . . .                    | <i>6</i>                  |
| <i>SET Systems</i> . . . . .                       | <i>8</i>                  |
| <i>Additional Products</i> . . . . .               | <i>18</i>                 |
| <i>A History of Success</i> . . . . .              | <i>22</i>                 |
| <i>The Future of SET Technology</i> . . . . .      | <i>24</i>                 |

Enventure's innovative, cost-reducing technology can be used for:

- » well slimming
- » remedial operations
- » window exit applications
- » horizontal well applications

All of Enventure's expansion processes are executed by specially trained personnel. Enventure emphasizes health, safety and environmental (HSE) standards before, during and after expansion. Standard operating procedures include a job safety analysis (JSA) review before each installation to ensure that everyone understands the process.

Attention and adherence to HSE practices have resulted in Enventure's impressive safety statistics of zero OSHA recordable incidents since 1999. This safety record for running SET Systems means there have been no lost time incidents and no medical treatment cases.

Whether running SET Systems as part of the well plan or using them as a means to salvage a challenging well, Enventure's SET Technology is an effective and affordable solution for a myriad of drilling and workover environments.

## The Enventure Solution

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**E**nventure's solution involves the controlled expansion of solid tubulars in the downhole environment to enhance drilling, production and remedial operations. Enventure works closely with you to implement a customized process for whatever tubular expansion applications you require.



The innovative systems that provide an individualized solution for your well consist of the following:

- » Openhole Liner (OHL™) System
- » Cased-Hole Liner (CHL™) System
- » FlexClad™ System
- » Openhole Clad (OHC™) System
- » VersaFlex™ Expandable Liner System
- » PoroFlex® Expandable Screen Completion System

The Enventure solution is best implemented as part of the original well plan, where ID (inside diameter)

pass-through can be optimized. However, SET Systems can also be used on a contingency basis. SET Technology has established a reputation as a successful solution for critical and unexpected downhole challenges.

Incorporating SET Technology into the drilling plan adds a new dimension to both the well design and system installation. Planning proven SET Systems into your well plan enables you to reach total depth (TD) with the desired completion string while beginning the well with a smaller hole. SET Technology enables operators to reach TD with a larger hole than with a conventional casing design, or to drill further and still maintain the required completion size.

In addition to the hole size options, SET Systems can work as a contingency to address hole conditions that would require casing to be set prematurely. By pre-planning a well with expandables, you can reduce impact by down-sizing items such as the rig, riser and wellhead equipment.

In a conventional well with a telescoping casing string, an operator must often change out the bottomhole assembly (BHA) and drillstring to accommodate the smaller casing. SET Technology can minimize the number of times the drillstring size must be changed. These factors help reduce the spread rate and expedite a quicker payback on capital costs.

Enventure considers the following criteria for all expandable installation designs:

- » casing size
- » mechanical properties of expandable tubulars
- » wellbore or hole conditions
- » downhole deployment
- » expanded pass-through ID

Considering the necessary criteria helps Enventure customize their systems to your well design or conditions. This process helps you realize not only the technical benefits gained from SET Technology but the financial savings as well.

As an example, an operator with a deepwater well in the Gulf of Mexico faced limited options when casing had to be set higher than planned. Typically, the operator would have set 9% in. casing at the original 11% in. casing depth, resulting in premature loss of hole size. Another option was a window exit out of the 13% in. casing. Estimates indicated 14 days to sidetrack at \$425,000/day and \$100,000 for whipstock tools and BHA. The cost to the operator was estimated at over \$6,000,000.

The operator instead chose SET Technology and ran a 9% x 11% in. expandable OHL System at an approximate cost of \$500,000. Incremental rig time came to \$425,000. By using SET Technology, the operator realized a total economic value in excess of \$5,000,000.

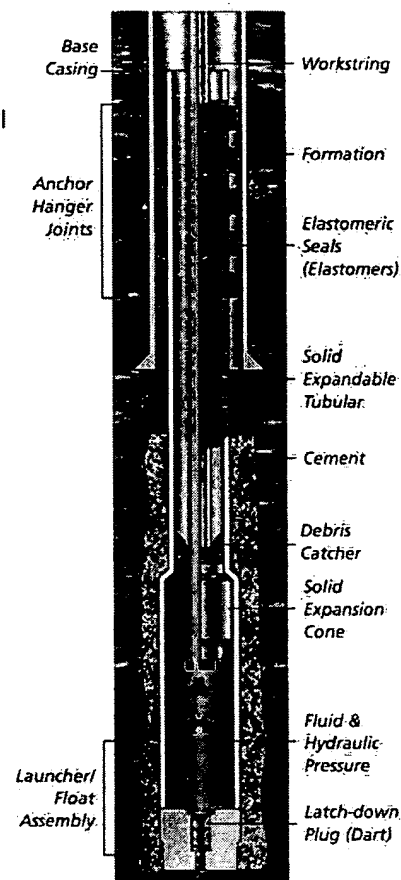
Enventure's expertise in the execution of SET Technology continues to garner an impressive savings reputation. SET Systems enabled a major oil company to re-enter an abandoned deepwater well and complete it, thus saving a \$40 million investment. Being able to salvage previously expended effort and investment distinguishes SET Technology as an economically feasible solution that significantly improves bottom line.



## SET Technology

SET Technology stemmed from Enventure's development of a cold-drawing process that permanently deforms the pipe without any additional heat beyond what is present downhole. This original procedure takes the steel beyond its elastic limit into the plastic region of the stress-strain curve while remaining safely below ultimate yield. SET Systems incorporate state-of-the-art technology with proven experience to expand casing downhole. Enventure's total solution includes the expertise and the equipment needed to apply the technology safely and with a high degree of reliability.

Enventure uses pipe with specifications that are considerably more stringent than those specified by API for well use but with pre-expansion properties similar to those of API L-80 material. The metallurgical composition of this pipe yields greater ductility while still retaining its strength properties. Enventure utilizes electric resistance welded (ERW) pipe, which provides greater uniformity of wall thickness, resulting in a more consistent expansion.





To facilitate the expansion process, the hole section is drilled and/or under-reamed, and the expandable casing is run. The launcher (the housing at the bottom of the SET System) contains an expansion assembly and a float assembly, and is typically constructed of thin-wall, high-strength steel.

The custom-designed expansion assembly contains a solid cone, which is driven through the expandable tubulars using hydraulic pressure and/or mechanical force, radially enlarging the tubular. Enlarging pipe diameter causes the pipe length to shorten as a result of material balance. The cone moves from the bottom up through proprietary pin-up connections. This bottom-to-top expansion process:

- » anchors and seals the expandable liner against the previous pipe string
- » ensures proper coverage by forcing pipe shortening to manifest at the top of the overlap section of the liner
- » makes it easier to pump through the workstring while picking up on it

When a liner is expanded, its OD increases significantly, while the wall thickness decreases only slightly. Enventure currently expands pipe 5-16%, though more aggressive expansion is possible. Depending on the expansion ratio, wall thickness is reduced by 2-5% during the expansion process.

The expandable system provides a positive seal in the liner lap, thus eliminating the need for expensive cement squeezes at the liner top.

## SET™ Systems

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### Openhole Liner (OHL™) System

Enventure's OHL System is the practical solution when designing the well plan for your most challenging prospects.

Enventure's OHL System solves problems associated with:

- » borehole instabilities
- » pore-pressure/frac-gradient issues
- » subsalt formations
- » wellbore tapering

These operational challenges can all result in the unplanned downsizing of the hole when casing must be prematurely set to remedy the situation. The expandable OHL System reduces the tapering effect, allowing you to continue drilling with optimal hole diameter. An optimized hole diameter in production zones results in higher flow rates, an attractive benefit in early field development.

The OHL System is run through the existing casing or liner. Once positioned in the open hole, the system is then expanded from the bottom up. When the solid expansion cone reaches the overlap between the OHL System and the existing casing, the cone expands an anchor hanger joint that provides a permanent seal between the OHL and the casing.



In exploration drilling, expandable liners can reach promising payzones and allow evaluation with conventional logging tools without running slimhole equipment. Formation evaluation tools for smaller hole sizes tend to be more costly, have limited availability and have a significantly higher failure rate.

In remediated wellbores, the expandable liner is a way to reach deeper reserves and isolate water zones that have been penetrated by horizontal re-entry wells. Lost circulation zones and shallow water flows can be controlled.

# Expandable Openhole Liner System





## Openhole Liner (OHL™) System Installation Sequence

**Drill Hole.** Drill an oversized open-hole interval.

**Run Expandable Liner.** Pick up the expandable liner, expansion assembly and launcher.

**Condition Mud, Cement Liner.** Run to the planned depth (or as deep as hole conditions allow) and perform cementing operations.

**Pump Plug.** Displace cement with latch-down plug.

**Latch Plug, Start Expansion.** Seat the latch-down plug and initiate expansion by expanding through the launcher.

**Expand Hanger Joint.** Expand the liner including the anchor hanger joint in the overlap between the SET and the base casing. Expand out of the top of the liner.

**Drill Out Shoe.** Continue with next drilling operation.

## *Cased-Hole Liner (CHL™) System*

The CHL System is run to repair or reinforce existing casing and to isolate perforated intervals. Anchor hanger joints are used to isolate these intervals and are placed at the top and the bottom of the liner. Additional anchor hangers can be placed anywhere along the length of the liner. By accommodating multiple anchor hangers, the CHL System enables you to isolate several zones with one liner.

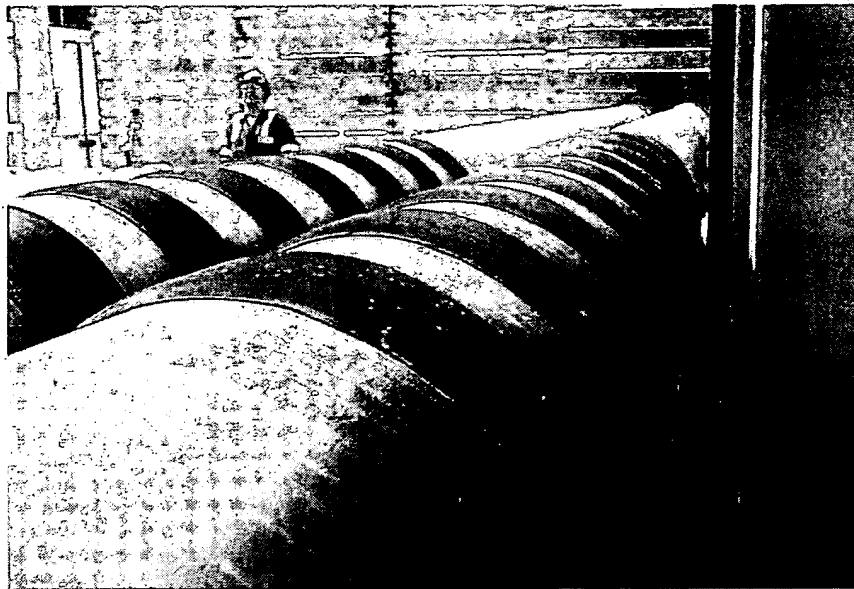
The elastomer bands on the anchor hanger joints can be supplied in a variety of compounds depending on downhole temperature and fluid compatibility. This system also allows you to use elastomer bands of different thicknesses on the same liner to seal in a variety of IDs. This versatility enables the system to address conditions such as casing corrosion, perforations in the casing, parted casing and/or leaking connections.

The CHL Systems can be run either bullplugged or with a float assembly. Running the CHL System with a float assembly allows for the circulation of fluid for:

- » well control purposes
- » removing any obstructions or debris in the wellbore
- » spotting packer fluid or other fluids

A drift assembly, run prior to installing the CHL System, simulates the launcher run to ensure the absence of restrictions during the actual installation. This important step is used to verify that the hole is obstruction-free and ready for expansion operations to commence. As the system is installed, the bottom-to-top expansion process provides a robust seal at each interval of elastomers.

The burst strength of the newly-repaired wellbore is frequently higher than that of the original casing. This allows you to run stimulation, wellbore treatment or fracturing operations under pressure.



# Expandable Cased-Hole Liner System



Clean Out  
Casing



Run and Position  
Expandable Liner

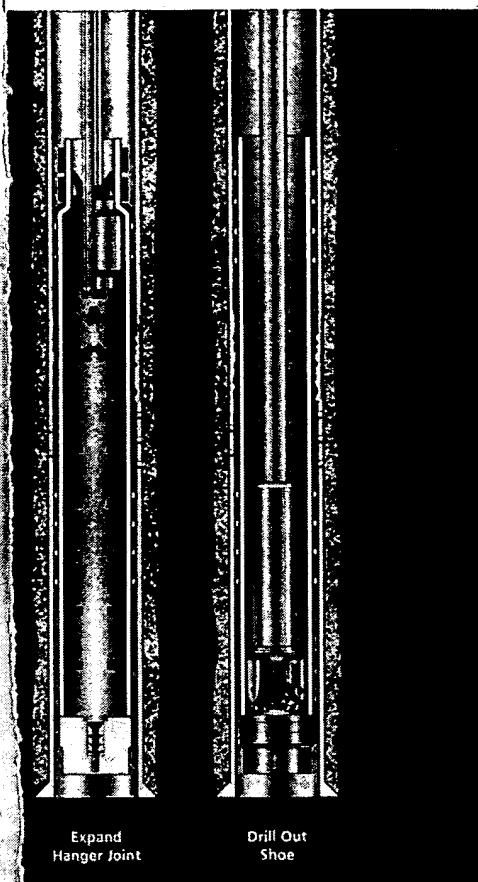


Pump Dart,  
Start Expansion



Expand  
Liner





## **Cased-Hole Liner (CHL™) System Installation Sequence**

**Clean Out Casing.** Prepare the wellbore for the installation using mills and/or scrapers, if necessary.

**Run and Position Expandable Liner.** Run the expandable CHL System in the well. Space-out and position the liner over the interval to be repaired or reinforced.

**Pump Dart, Start Expansion.** Seat the latch-down plug and initiate expansion by expanding through the launcher.

**Expand Liner.** Pressurize workstring and pump expansion cone while pulling up on workstring.

**Expand Anchor Hanger Joint.** Continue expansion until the cone exits the top of the liner and pressure test the installation.

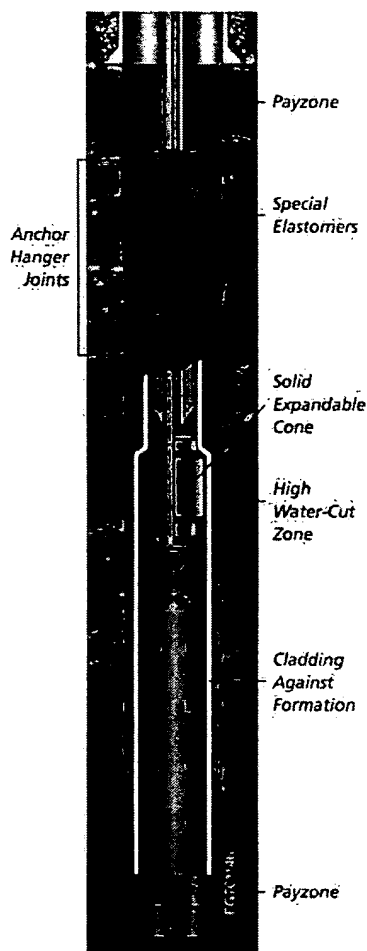
**Drill Out Shoe.** Prepare the well for further completion or production operations.

## Openhole Clad (OHC™) System

The OHC System incorporates special elastomers that enable this system to be used in a variety of applications. For example, formation stability can be provided for horizontal wells in the production stages. In these wells, the OHC System straddles lost circulation zones and/or provides water shut-off in the open hole. The OHC System consists of expandable pipe for the length of open hole to be isolated and a pre-expanded pipe section that houses the float assembly and expansion cone.

The OHC System uses anchor hanger joints at each end of the liner. Additional anchor hangers can be placed anywhere along the length of the liner to affect a seal against the open hole. Because the system only covers the problem area, you realize substantial savings by not having to seal the entire open hole.

A sufficient length of liner in the appropriate sized diameter is used to seal off the problem area by expanding against the formation wall. The clad becomes anchored as soon as the first seal element is expanded. This configuration eliminates the need to tie back into the base casing because sealing occurs directly against the formation.



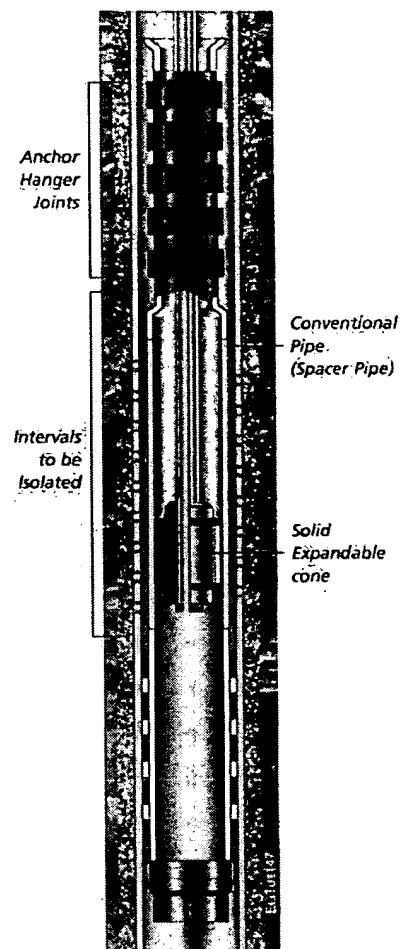
*Enventure's OHC System uses anchor hanger joints which allow the system to be customized for a myriad of hole sizes.*

## *FlexClad™ System*

Enventure's FlexClad System repairs existing casing, isolates perforated sections and provides a gas-tight liner. This system consists of expandable sealing sections called Flex Hangers, conventional API tubulars that act as spacer joints and flush joint connections. The Flex Hangers are separated along the length of the liner using spacer pipe, enabling this system to be used in smaller casing sizes. The FlexClad System differs from Enventure's standard expansion systems in that the liner and connections are not expanded.

The FlexClad System is run with a launcher that is either open or bullplugged. If the launcher is open, a dart is dropped after the system is run into the well and positioned.

When the cone meets a Flex Hanger section, expansion pressure is applied through the workstring to drive the cone through the hanger body. The cone is then raised to the next Flex Hanger section, moving through the conventional pipe and connection without expanding. The expansion process continues at each Flex Hanger section until the cone exits the top of the liner.



*The FlexClad System adapts SET Technology to high-temperature, high-pressure applications.*

## *Additional Products*

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The basic technology utilized to develop Enventure's SET Systems helped to establish other expandable tubular products. Companion products co-developed by Enventure include Halliburton's VersaFlex™ Expandable Liner System and PoroFlex® Expandable Screen Completion System.

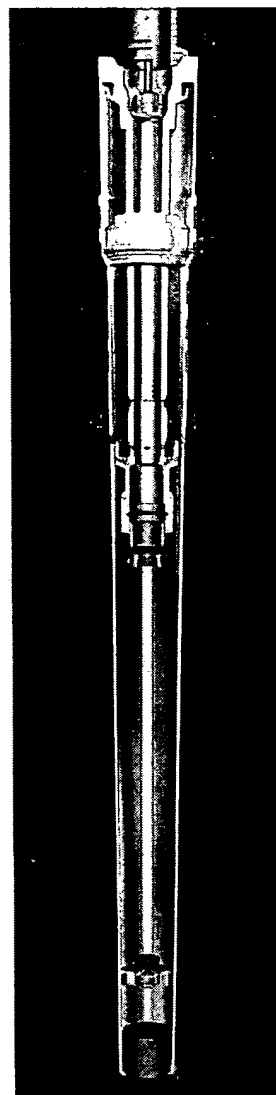
### *VersaFlex™ Expandable Liner System*

The VersaFlex Expandable Liner System, which contains no moving parts, is run when a conventional liner system is to be installed. With its polished bore (PBR) receptacle and expandable solid hanger body, the VersaFlex System provides a bi-directional annular seal and all tensile and compressive-load capability. This system:

- » eliminates liner top isolation packers
- » reduces rig time because of faster run-in-hole (RIH) operations
- » improves reliability and fluid flow
- » eliminates slip damage to supporting casing
- » eliminates expensive cement squeezes to achieve liner top isolation

The VersaFlex System uses a setting ball that when dropped lands on a ball seat and seals off fluid pressure in the liner below. This action opens a port above the expansion cone and initiates expansion. As workstring pressure reaches propagation pressure, the expansion cone moves downward, expanding the VersaFlex System. Once the VersaFlex System is expanded, elastomeric elements provide a dynamic seal against the existing casing string.

*Halliburton's VersaFlex Expandable Liner System consists of the hanger body, integral packer, integrated PBR and liner setting sleeve with integral cementing pack-off.*



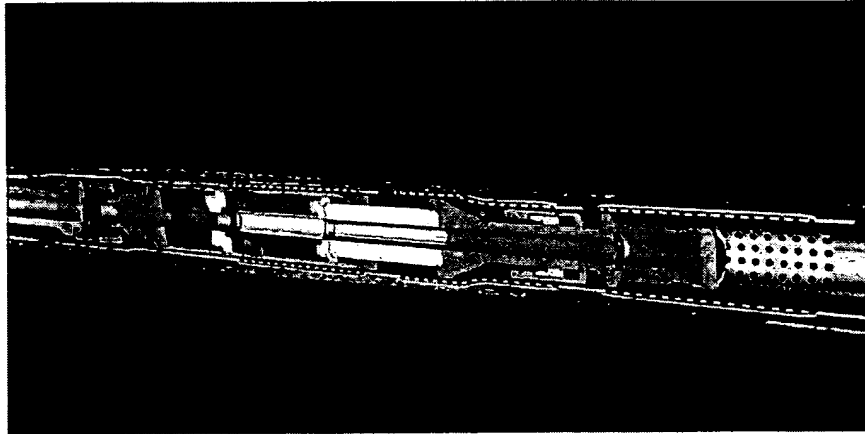
## ***Poroflex® Expandable Screen Completion System***

The Poroflex Expandable Screen Completion System provides filtration to prevent sand production in producing well formations that can sometimes become unstable. This expandable filtration system with enhanced collapse strength integrity allows you to stabilize the borehole by expanding the screen OD to or near the borehole ID. The Poroflex System allows you to:

- » eliminate or reduce borehole/screen annulus
- » minimize plugging of non-uniform sands
- » minimize pressure drops in horizontal intervals
- » eliminate gravel pack failures

The system's perforated solid base pipe strengthens the sand screen and a one-piece sintered laminate screen provides filtration integrity under a variety of load conditions. The system also allows you the option of expanding either mechanically or hydraulically. Additional benefits to running the Poroflex System include:

- » larger ID for easier well intervention access
- » isolation of trouble zones with solid expandable tubulars
- » high resistance to erosion and plugging
- » formation support that lowers skin values



*Halliburton's PoroFlex Expandable Screen Completion System includes a screen, running tool, screen hanger and screen-expansion tool.*

## *A History of Success*

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Enventure secured its reputation as the leader in solid expandable technology by commercializing a viable product only two years after the first proof-of-concept test was conducted. Since its inception in 1998, Enventure has put development and commercialization of SET Technology on a fast track, commercializing four products in less than five years. Enventure continues to refine SET Technology, broadening the range of applications with diverse capabilities.

Enventure and Brunei Shell Petroleum installed the world's first horizontal CHL System in a 1,000-foot-plus workover project off the northwest coast of Borneo. This complex job called for the elastomer seals to be positioned within a tolerance of  $\pm 6.6$  ft due to the proximity of the gas to oil-bearing zones. The liner was run "uphill" in an inclination of 105 degrees to get to a hole depth of 13,123 ft.

Enventure confirmed the ability to sidetrack out of casing and expand through a window when Kerr-McGee used the window exit capability in the Gulf of Mexico. Enventure installed and expanded a 7% x 9% in. OHL System inside 9% in. casing. The successful expansion of the 2,222-ft OHL System with a setting depth of 1,964 ft below the window enabled Kerr-McGee to maintain completion size at TD. Because of its flexibility, the system can accommodate horizontal, vertical and high angle holes.

Enventure installed the first corrosion-resistant alloy (CRA) SET System in a Shell NAM well. Expanding a 6 x 7% in. 13Cr CHL increased the productivity of the well. This well proved the viability of using CRA materials in SET installations for low-pressure gas wells. At the time, the installation also was the longest solid tubular expansion in a single run: 6,095 ft.





Enventure's first application of an Openhole Clad (OHC) System was for Petroleum Development Oman (PDO), which was also the first clad installation set in a horizontal well section. PDO opted to set two OHC Systems, from 5,930 to 6,017 ft and from 6,181 to 6,220 ft, to shut off approximately 2,516 bbl/day (400 m<sup>3</sup>/d) of produced water. This installation also marked the first elastomeric sealing of a SET System directly against the formation.

Enventure introduced SET Technology as a practical drilling design element in Chesapeake Energy Corp.'s Wellman 3-H well in South Texas. A 5% x 7 in. expandable OHL System was run and expanded inside a previously installed 6 x 7% in. expandable system. This expandable "nesting" process minimized the reduction of hole size at 12,470 ft TD.

This versatile technology can be used with a nesting application and with an expandable/conventional/expandable configuration. This frequently used well plan typically entails expanding a 9% in. OHL System in 11% or 11% in. base casing. To complete the well plan, 9% in. casing is installed and a 7% x 9 in. OHL System is run and expanded. The 9% in. casing, specially made to facilitate expandable well planning, is now available. This combination of expandable and conventional tubulars has been run by world-class operators to reach deepwater and ultra-deepwater discoveries.

## *The Future of SET™ Technology*

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**P**lanning solid expandable tubulars into the well design enables you to aggressively pursue promising production zones and still avert the unexpected drilling situations. Hard to reach pay zones become accessible and challenging well situations become manageable.

SET System enhancements and increased reliability continue to push the application boundaries of this enabling technology, actualizing valued benefits now. Planning expandables into your well design offers 40-50% of the features and benefits expected from the next step in wellbore construction – Enventure's MonoDiameter™ System.

While planned SET Systems reduces the telescoping effect in traditional well design, the MonoDiameter System will eliminate telescoping altogether, slimming down the top of the well while increasing well diameter at TD. The MonoDiameter System exhibits the ultimate in diametric efficiencies – a constant ID from the top of the well to TD.

The MonoDiameter Process over-expands the junctions of the nested expanded casing liners, resulting in a single-diameter wellbore. Nesting sequentially installed expandable casing strings can decrease the reduction of a typical hole size by 50% and enable drilling to continue as deep as necessary to reach the payzone. The MonoDiameter System will provide the total benefits of expandable tubular technology by:

- » Decreasing the number of casing sizes needed in inventory
- » Standardizing drillpipe sizes and bottomhole assemblies
- » Reducing
  - rig, riser and BOP sizes
  - cement and mud volume
  - bit sizes and cuttings disposal

The first MonoDiameter field application was in a South Texas well for Shell Exploration & Production Company (SEPCo). A 9% in. MonoDiameter Drilling Liner was installed in 11 $\frac{3}{4}$  in. casing and expanded to a 9.9 in. ID. The liner lap was hung and sealed with elastomers. The shoe was drilled out and a top-down cone expanded the casing to a 10.4 in. ID. After the subsequent hole section was underreamed, another 9% in. MonoDiameter Drilling Liner was run and expanded. A drift run to TD confirmed the expanded diameter and both liners tested successfully to 4,000 psi.

Although the MonoDiameter System will bring even more opportunities to reduce costs and develop reserves, Enventure's current catalog of solid expandable systems enable you to realize these benefits now on a modest scale. Operators worldwide are planning SET Systems into their well designs to access hard to reach production zones, avert unexpected downhole conditions, and drill in environmentally-sensitive areas.

Enhanced systems, refined procedures, and innovative research and development reflect Enventure's commitment and ability to deliver tomorrow's technology today.

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